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APPLICATION OF FLUOROMETALLIC SCREENS FOR PAPER RADIOGRAPHY

J. C. DOMANUS

Risø National Laboratory, DK-4000 Roskilde, Denmark
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APPLICATION OF FLUOROMETALLIC SCREENS

FOR PAPER RADIOGRAPHY

by

J. C. DOMANUS

Nuclear Department
Elsinore Shipbuilding and Engineering ., LTD.*

1. INTRODUCTION

Paper radiography seems to have developed into well- established technique of industrial radiography. Up till now radiographic paper was used mainly with fluorescent intensifying screens. Only in very rare instances is it used without intensifying screens, as one of the main advantages of paper-radiography is its relative speed, due to the high intensification factor of the fluorescent screen.

Many details about the properties of the radiographic paper, sensitometric properties of the various paper and screen combinations, as well as several examples of the application of paper radiography can be found in previous reports published by the author on that subject [1 to 7].

2. FLUOROMETALLIC INTENSIFYING SCREENS

Fluorometallic intensifying screens for industrial film radiography have been available for many years Some technical data about the Kyokko screens are given below. Figure 1 shows the structure of a fluorometallic screen.

* Work performed under contract with Risø National Laboratory

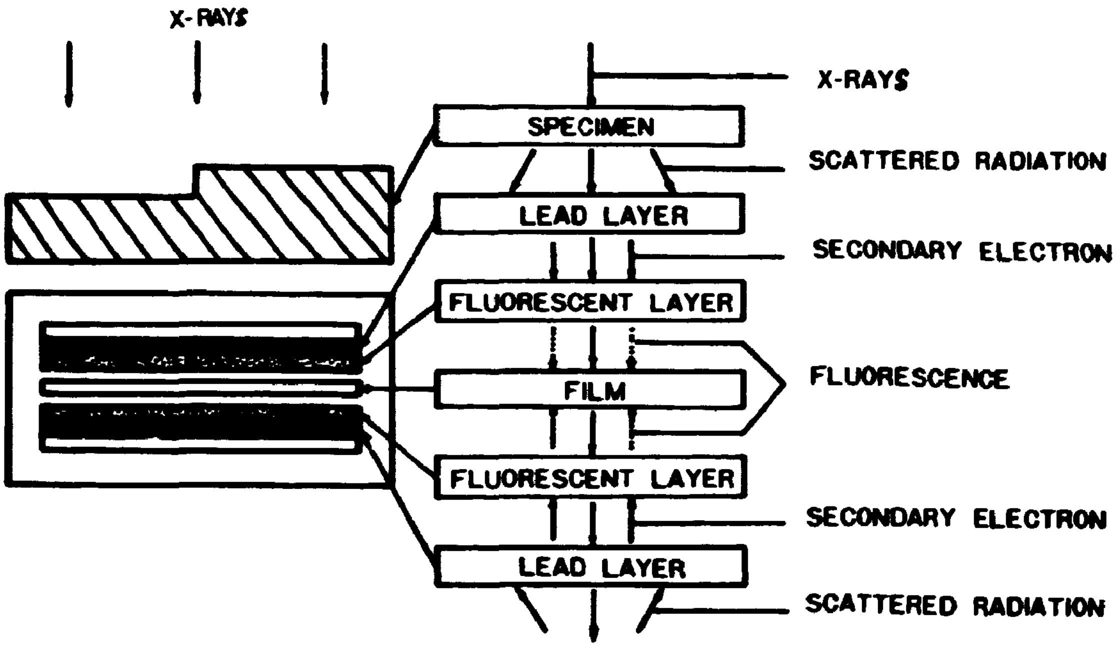

Fig.1 The structure of a fluorometallic screen

In table 1 different Kyokko fluorometallic screens are listed, together with their range of application.

Table 1. Kyokkko fluorometallic screens

Types		X-ray Voltage Range and γ-ray Source	Material and Thickness	Intensification Factor	
				Fuji # 100	Fuji # 400
SMP-108	Hi Definition	80 ~ 300 kV Tm-70	Light Metals, Alloys 0~200 mm Steel, Copper 0~ 50 mm	5 ~ 9	45 ~ 65
SMP-308	Hi Speed			16 ~ 24	105 ~ 165
SMP-103	Hi Definition	200 ~ 1000 kV Ir-192, Cs-137	Steel, Copper 30~100 mm	4 ~ 6	30 ~ 50
SMP-303	Hi Speed			8 ~ 12	50 ~ 85
SMP-101	Hi Definition	1 ~ 35 MeV Co-60, Ra-226	Steel, Copper 50~200 mm	3 ~ 5	20 ~ 30
SMP-301	Hi Speed			5 ~ 9	35 ~ 55

The merits of those screens (distributed by Mitsubishi Chemical Industries) are described as follows:

"MCI fluorometallic screens (SMP) are equipped with both the merits of lead foil screens and salt screens while covering up the failings of these two screens".

"1. Available for testing in pipe lines, ships, large valves, high pressure plants, atomic pile reaction towers and cast steels.

2. Tube voltage can be lowered. Therefore, even thick object can be taken radiographically by means of small capacity equipment.

3. Radiographic testing time can be largely reduced.
4. Contrast is improved and fault sensitivity is elevated.
5. Particularly effective when used with γ-ray source (^{192}Ir) short in half-life."

One of the reasons why the application of fluorometallic screens to film radiography was not very popular was the fact that the spectral sensitivity of X-ray films and fluorometallic screen were not matched together.

Trying to overcome this drawback Agfa-Gevaert has recently introduced a complete system of X-ray film and fluorometallic screen, called the Structurix RCP. According to the manufacturer "Structurix RCP film is a high-contrast X-ray film, specially designed for use with fluorometallic screens". This film is "sensitive to X-and gamma-rays, UV-, violet and blue rays, and to rays emitted by the fluorometallic screen".

The Structurix RCP fluorometallic screens are described by Agfa-Gevaert as having "hard wearing, high intensification, little screen unsharpness". "The structurix RCP fluorometallic screen is strongly fluorescent and ensures very good sharpness. The extra-strong protective coating in conjunction with the polyester base render the screen particularly durable. The screen is highly flexible, perfectly flat and moisture and stain resistant. Its surface can be cleaned with water, soap and water, or benzene. Due to its uniform and unchanging qualities, the kilovoltage does not have to be varied when replacing screen".

3. SCREENS USED FOR PAPER RADIOGRAPHY

Up till now radiographic paper was used mainly with fluorescent intensifying screens. Agfa-Gevaert, which has put on the market its IC system describes the Structurix IC screens (used in this system) as high intensification low screen blur: "The Structurix IC screen Type II is a high-definition screen which is strongly fluorescent and has no afterglow. It has a long life, can be kept clean quite easily, and has been treated against static. It has a hard surface, reinforced edges and a polyester base. This screen is moreover dimensionally stable, perfectly flat, as well as damp-and stain-proof. The surface of the structurix IC screen may be cleaned with soap and water, or pure benzene. The screen may be exchanged without altering the irradiation dose, thanks to the uniform and constant intensification guaranteed by each screen. Only one intensifying screen is used during exposure".

4. SPECTRAL SENSITIVITY

The spectral sensitivities of the Structurix IC paper, the Structurix IC type II screen, the Structurix RCF film and Structurix RCF fluorometallic screen are compared in fig. 2 (according to Agfa-Gevaert pamphlets).

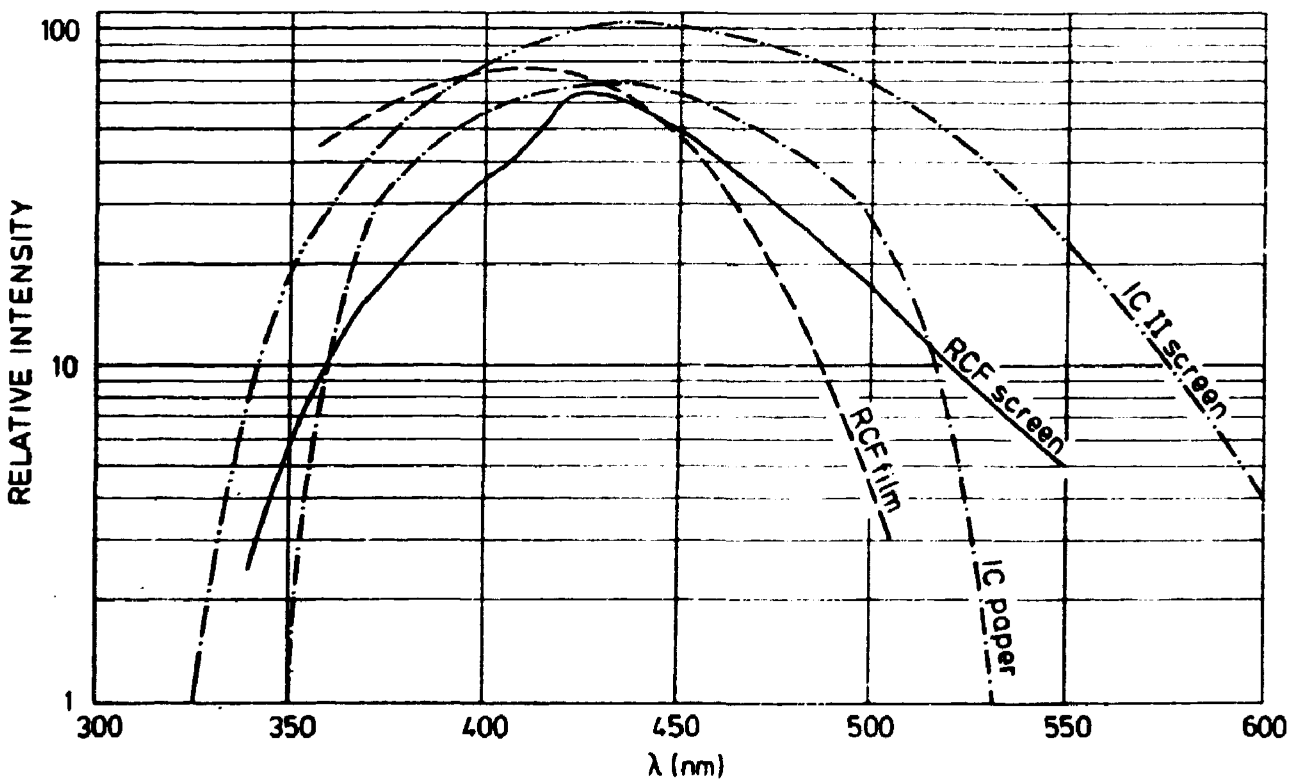

Fig. 2. Spectral sensitivity of Structurix paper, film, and screens

As can be seen, each shows its maximum spectral sensitivity at wavelength between 400 and 450 nm.

5. FLUOROMETALLIC SCREENS FOR PAPER RADIOGRAPHY

In the previous investigations [1 to 7] it was found that best radiographic results can be obtained if the radiographic paper is exposed through a thin lead filter. At kilovoltages above 50 kV it is recommended that a 0.05 mm thick lead filter atop the cassette (with paper and screen) be used.This filter can be permanently built into the cassette between its front lid and the fluorescent screen.

With this in mind as well as the fact that the fluorometalic screen has almost the same spectral sensitivity as the fluorescent screen, we have conclude that it might be advantageous to use a single fluorometallic screen instead of the lead filter and the fluorescent screen combination.

The investigation described below was aimed to prove the correctness of this theory.

6. SENSITOMETRIC PROPERTIES

First the sensitimetric properties of the Structurix IC paper exposed without screens and then with fluorescent IC II, as well as fluorometallic RCF screens were compared.

From characteristic curves relative speed, contrast and, exposure latitude could be computed.

6.1. Characteristic curves

In fig. 3 characteristic curves for 45 kV are given whereas fig. 4 gives similar curves for 50 kV. All curves were taken with a constant potential X-ray machine (Balteau 50 kV) having a beryllium window X-ray tube. To simulate practical radiographic conditions the paper was exposed through 15 or 20 mm of aluminium.

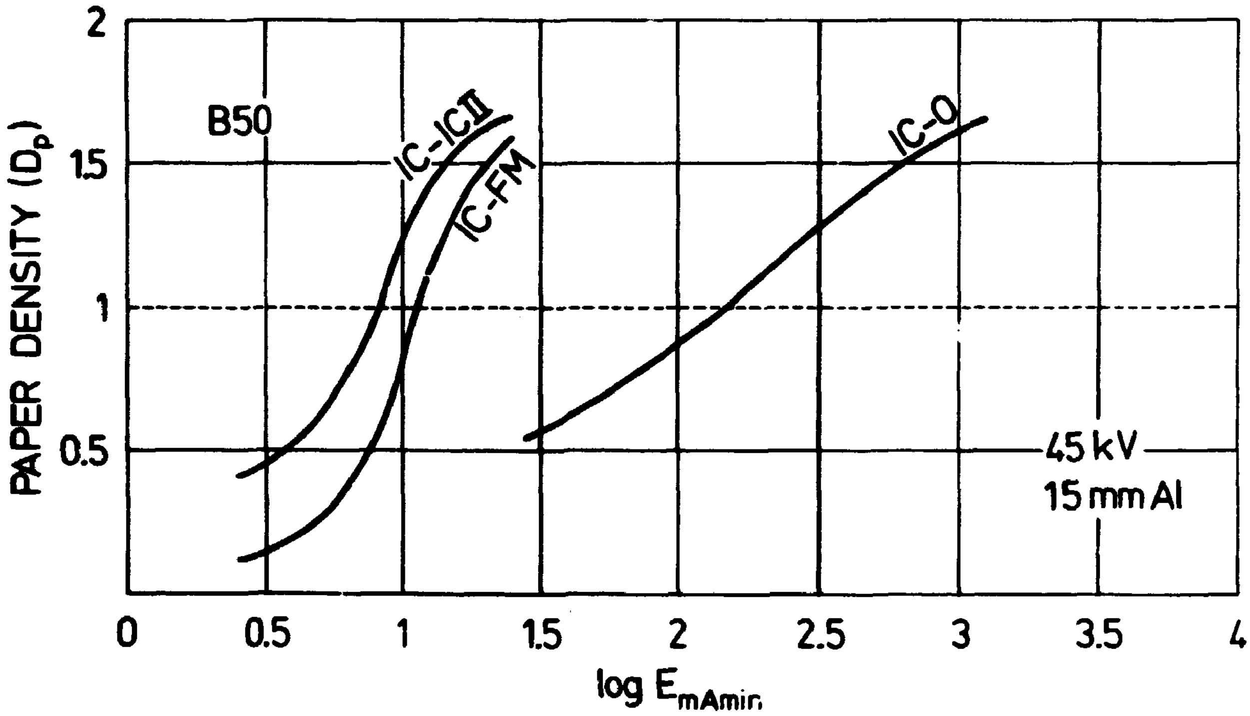

Fig. 3. Characteristic curves of the structurix IC paper taken at 45 kV through a 15 mm Al filter.

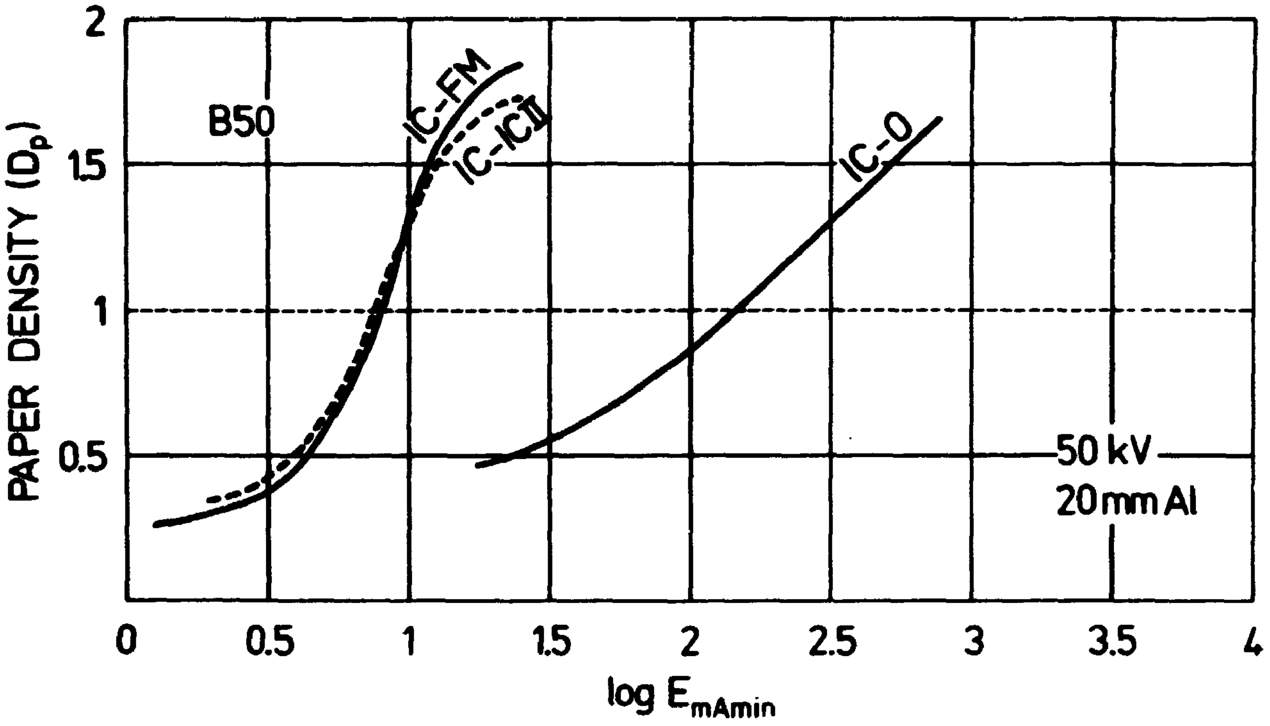

Fig. 4 Characteristic curves of Structurix paper taken at 50 kV through a 20 mm Al filter

Thereafter, the same combinations of paper and screens were exposed at 100 and 190 kV, through 30 mm Al or 20 mm Cu respectively. Here self-rectified X-ray machines were used (Andrex 180 and 300 kV). For the IC paper exposed without and with IC II screen a 0.05 mm Pb filter was used atop the cassette.

Fig. 5 shows the results for 100 and 190 kV.

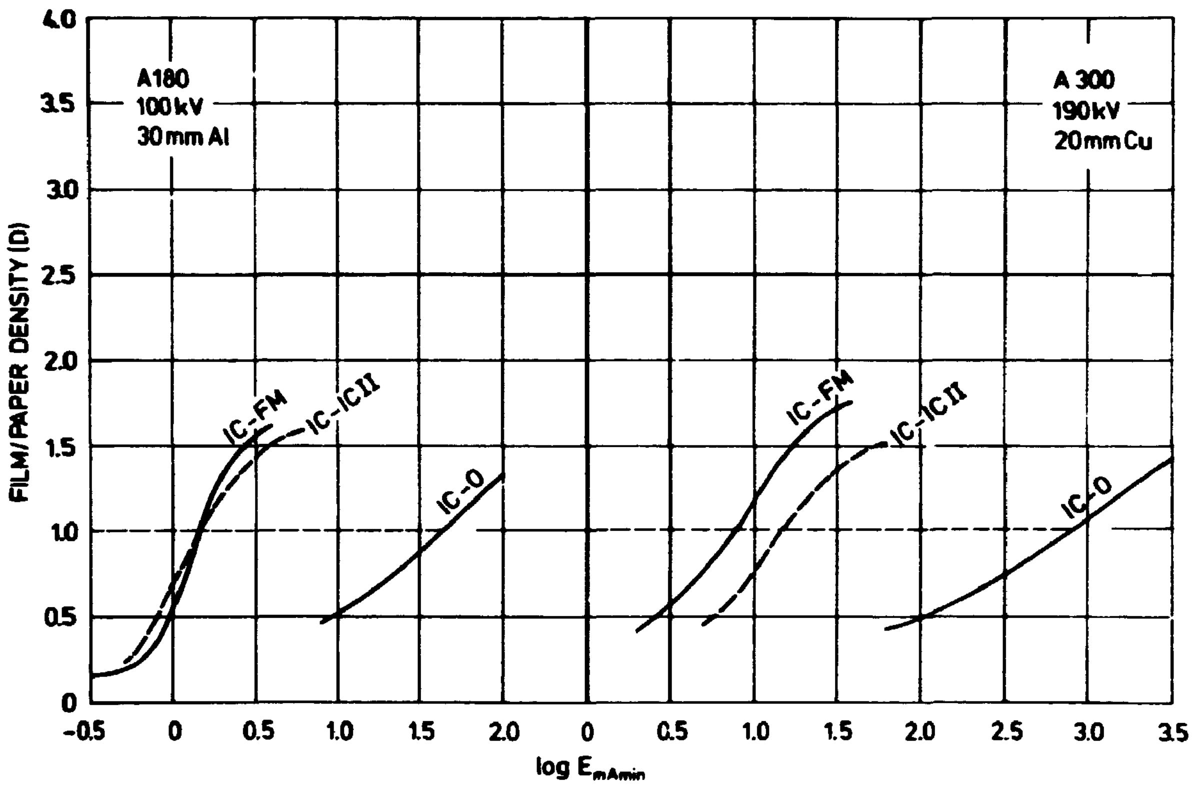

Fig. 5. Characteristic curves of Structurix IC paper taken at 100 and 190 kV through 30 mm Al and 20 mm Cu filters

6.2. Relative speed, contrast and exposure latitude

Using the same criteria as described in [1] relative speed, contrast, and exposure latitude were computed from the characteristic curves given above.

The relative speed was calculated as the relation between the exposure (in mAmin) necessary to obtain paper density of $D_p=1.0$ for paper exposed without and with intensifying screens. This is also called the <u>intensification factor</u> for a given screen.

The <u>contrast</u> was calculated as $\gamma = tg\alpha$, by measuring the angle (α) of the tangent to the characteristic curve at $D_p=1.0$.

The <u>exposure latitude</u> was calculated for the maximum acceptable paper density $D_p=1.3$ and the acceptable minimum limit of $D_p=0.5$.

All the above mentioned values are tabulated in table 2.

Table 2. Relative speed, contrast and exposure latitude

X-ray apparatus		Balteau 50 kV						Andrex					
								180 kV			300 kV		
Kilovoltage		45			50			100			190		
Filtration		15 mm Al			20 mm Al			30 mm Al			20 mm Cu		
Paper	Screen	S	C	L	S	C	L	S	C	L	S	C	L
IC	0	1.0	0.81	14.5	1.0	0.9	13.2	1.0	0.9	9.8	1.0	0.7	20.0
IC	IC II	18.2	2.6	3.0	18.6	2.5	2.5	30.2	1.9	2.9	52.5	1.3	4.7
IC	RCF	13.5	5.0	2.0	17.8	2.9	2.3	30.2	3.0	2.1	100.0	1.4	4.6

S-relative speed, C-contrast, L-exposure latitude.

7. EXPOSURE CHARTS

Exposure charts, reported previously in[1] for the Structurix IC paper exposed with IC II screens are reproduced below together with those taken for IC paper with RCF fluorometallic screens.

In fig. 6 exposure chart for Al and IC + IC II is given [1].

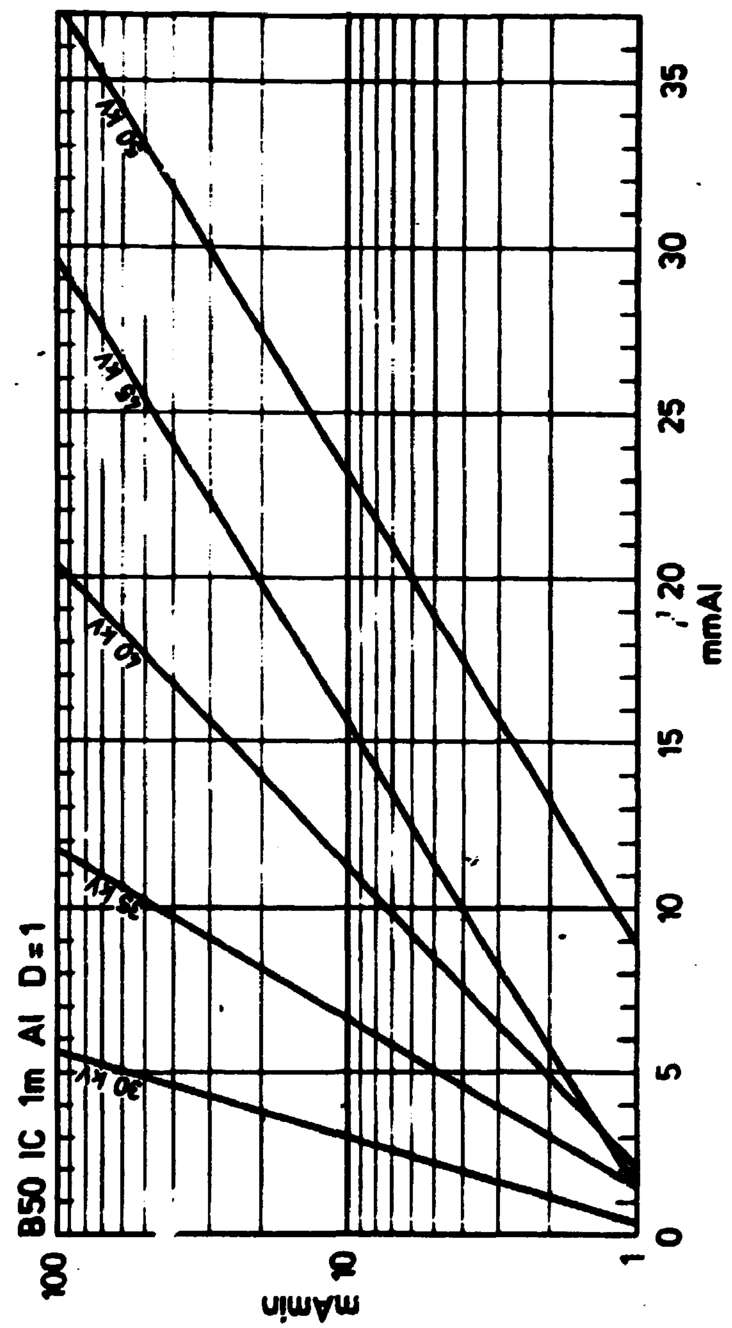

Fig. 6. Exposure chart for Al (IC paper with ICII screen)

It was taken with a constant potential X-ray machine with a beryllium window tube.

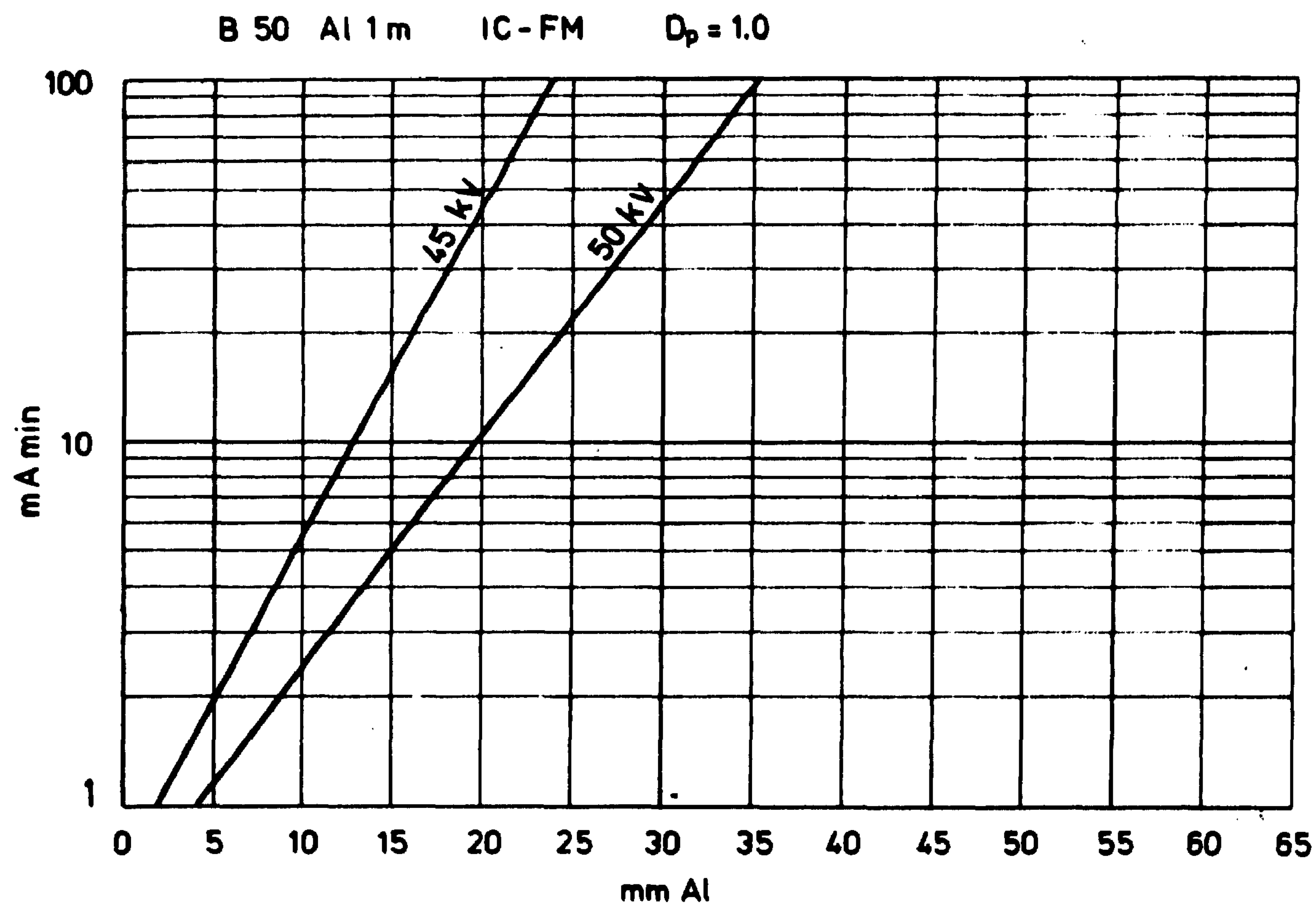

Fig. 7. Exposure chart for Al (IC paper with fluorometallic screen)

A similar exposure chart for Al is reproduced on fig. 7 for IC paper with fluoromet allic screen. It was taken with the same X-ray machine as for fig. [6]. Only charts for 45 and 50 kV are given, because it is impractical to use fluorometallic screens (containing lead) for lower kilovoltages.

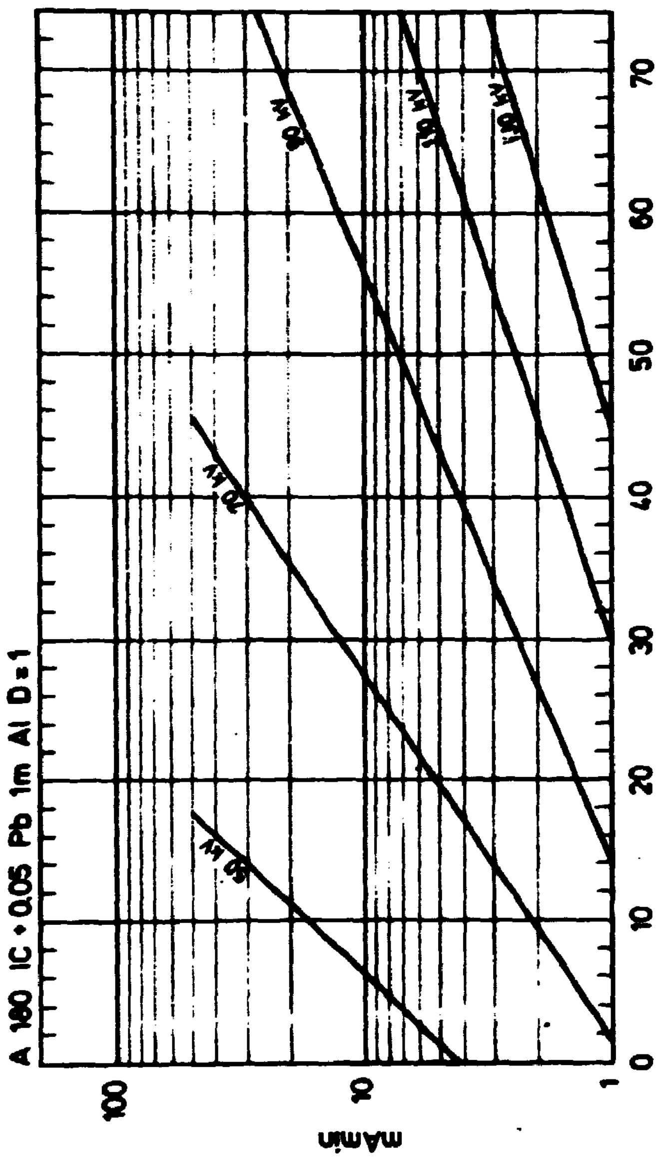

Fig. 8. Exposure chart for Al (IC paper with IC II screen)

On fig. 8 exposures charts are given for Al and IC paper exposed with IC II screen[1]. Here a self-rectified X-ray machine was used. On the cassette a 0.05 mm Pb filter was placed.

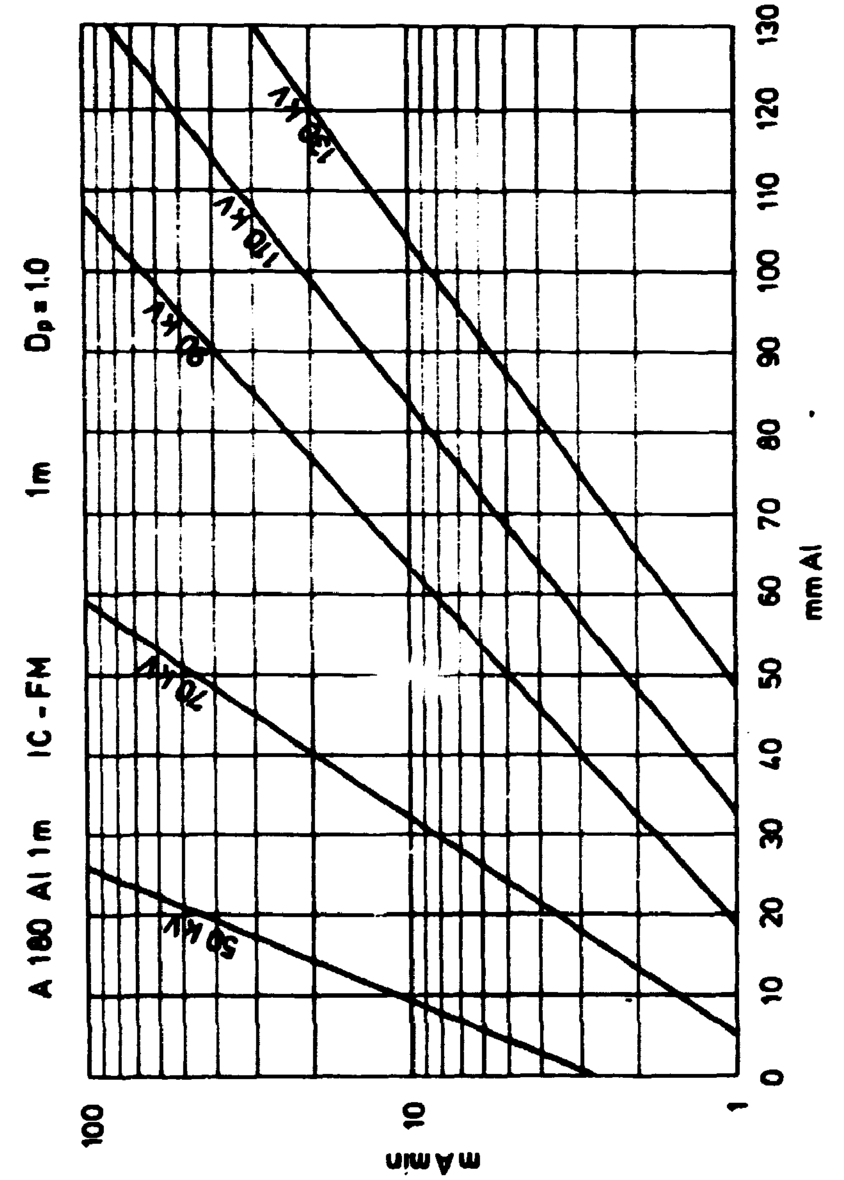

Fig. 9. Exposure chart for Al (IC paper with fluorometallic screen)

A similar exposure chart for fluorometallic screen is given on fig.9

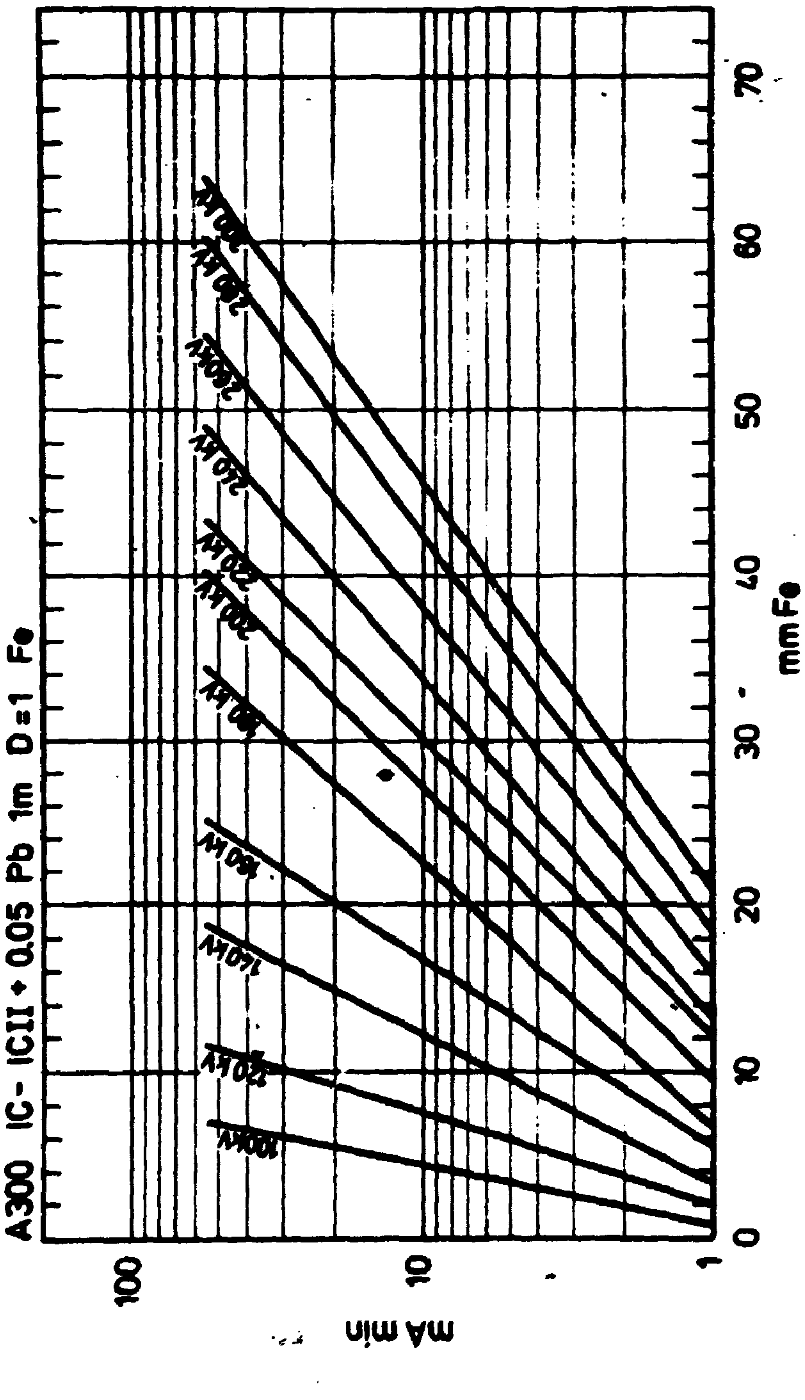

Fig. 10. Exposure chart for Fe (IC paper with ICII screen)

Finally on fig. 10 an exposure chart for steel is reproduced from[1], where a self-rectified X-ray machine was used and the exposures were made through 0.05 mm Pb filter.

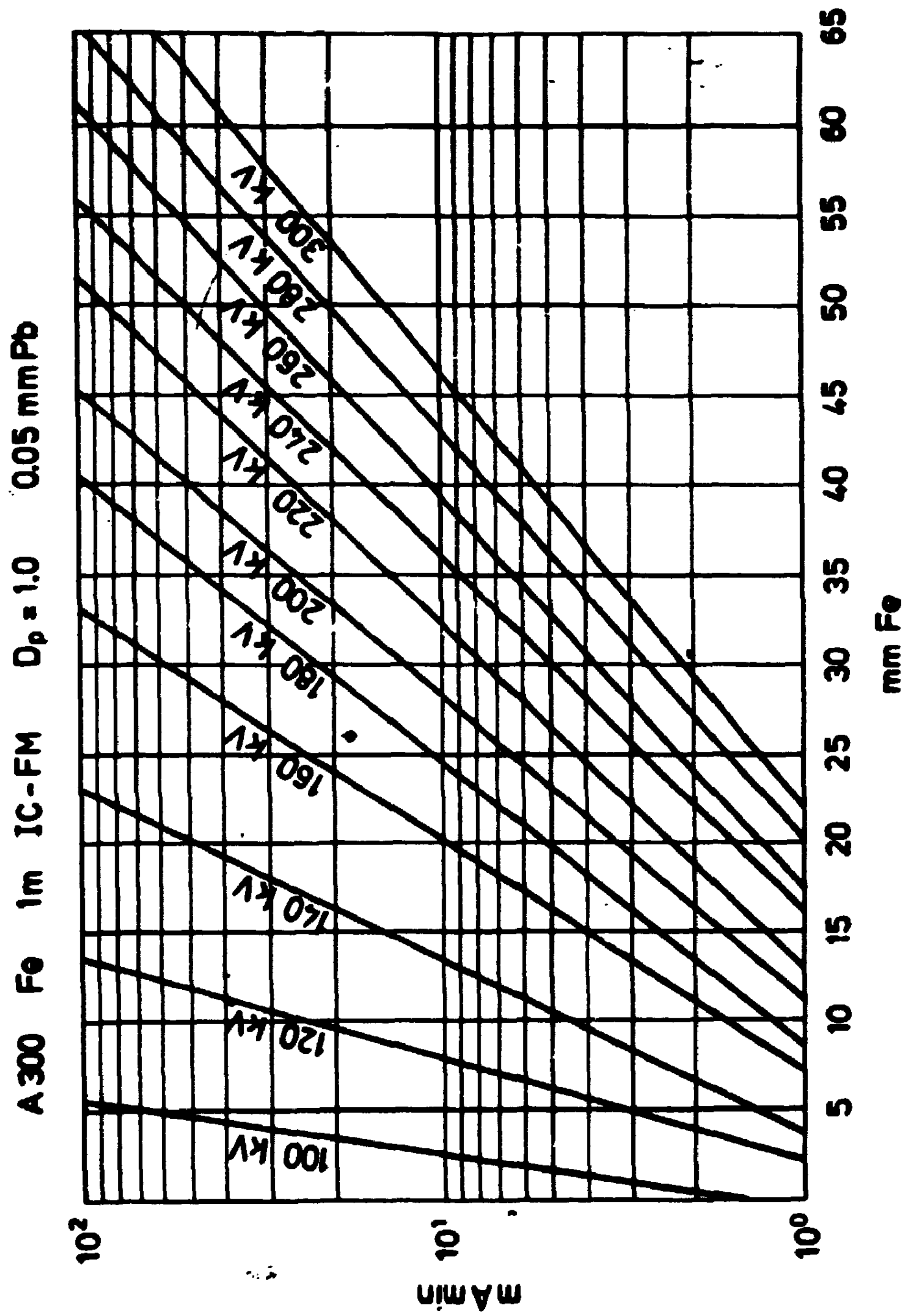

Fig. 11. Exposure chart for Fe (IC paper with fluorometallic screen)

In fig. 11 similar exposure chart is given for fluorometallic screen.

From the exposure charts the relative speed of the IC paper with fluorometallic screen vs. IC paper with IC II screen can be calculated (IC + IC II combination taken as relative speed 1).
The results of such calculations are reproduced in table 3. The relative speed was calculated for such thicknesses of Al and Fe which have required an exposure of 10 mAmin for different kilovoltages for the IC + IC II combination (those thicknesses are listed in table 3). For the sake of comparison in table 3 relative speeds calculated in the same way from the characteristic curves (see 6.2 above) are quoted.

8. RADIOGRAPHIC IMAGE QUALITY

The comparison of the radiographic image quality was made according to the method described in|5,6|. Here ISO wire IQI's and ASTM penetrameters were used together with 30 mm Al and 10 mm Fe plates.

Radiographic IC paper with IC II and fluorometalic screens was exposed according to the constant exposure technique, as described in|3|.

When exposed with 30 mm Al for 25 mAmin it was necessary to use 62.5 kV for the IC + FM or 66 kV for the IC + ICII combination to reach the paper density of $D_p = 1.0$. When exposed with 30 mm Al for 170 kV it was necessary to use 0.138 mAmin for IC + ICII and 0.169 mAmin for IC + FM.
The same experiment was repeated with 10 mm Fe and the results were the following: at 100 mAmin it was necessary to use 110 kV for IC + FM and 112 kV for IC + ICII. At 215 kV it was necessary to use 0.56 mAmin for IC + FM and 0.66 mAmin for IC + ICII.

The results of this investigation are shown in fig. 12 and 13 for aluminium and figs 14 and 15 for steel.

Table 3. Relative speed of IC + FM vs. IC + IC II for Al and Fe calculated from characteristic curves and exposure charts

Material	mm	kV	X-ray machine	Relative speed	From C.c.	From E.c.	From C.e	Remarks
Al	15	45	B 50	0.74	X			
Al	20	50	B 50	0.96				
Al	30	100	A180	1.00	X			
Cu	20	190	A300	1.90	X			
Al	15.5	45	B 50	0.56		X		
Al	23	50	B 50	0.63		X		
Al	6	50	A180	1.61		X		
Al	27	70	A180	1.56		X		
Al	56	90	A180	1.52		X		
Al	66	110	A180	1.11		X		At 5 mAmin
Al	68	130	A180	1.14		X		At 2.5 mAmin
Fe	4.4	100	A300	0.23		X		
Fe	7.5	120	A300	1.14		X		
Fe	12.2	140	A300	1.28		X		
Fe	16.8	160	A300	1.89		X		
Fe	22.6	180	A300	1.33		X		
Fe	27.0	200	A300	1.18		X		
Fe	30.0	220	A300	1.32		X		
Fe	33.8	240	A300	1.35		X		
Fe	38.0	260	A300	1.14		X		
Fe	42.4	280	A300	1.05		X		
Fe	47.6	300	A300	0.99		X		
Al	30	170	A180	0.82			X	
Fe	10	215	A300	1.18			X	

C.c.-characteristic curves: E.c.-exposure charts: C.e.-constant exposure

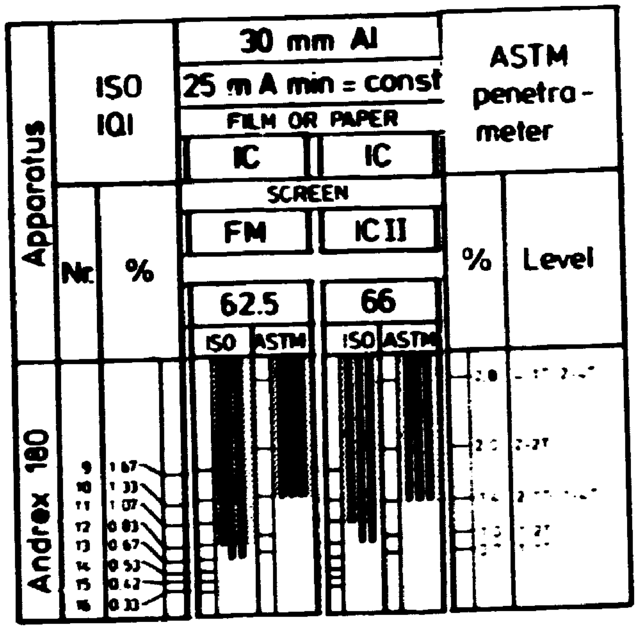

Fig. 12. Radiographic sensitivity for 30 mm Al exposed at 25 mAmin

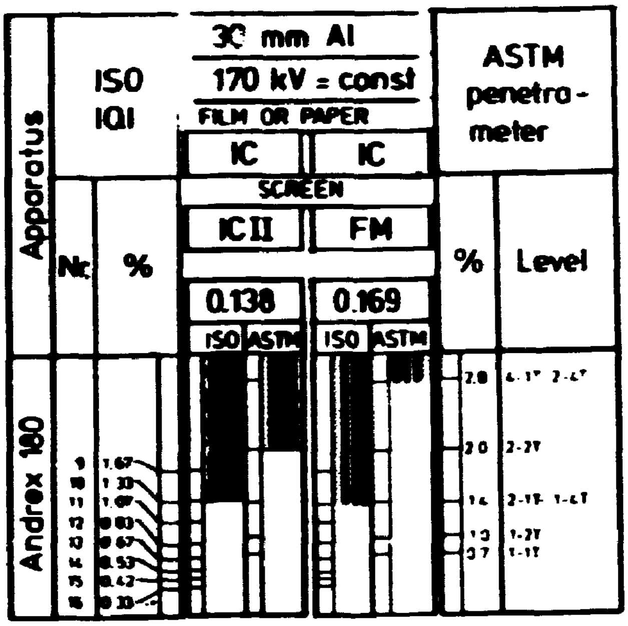

Fig. 13. Radiographic sensitivity for 30 mm Al exposed at 170kV

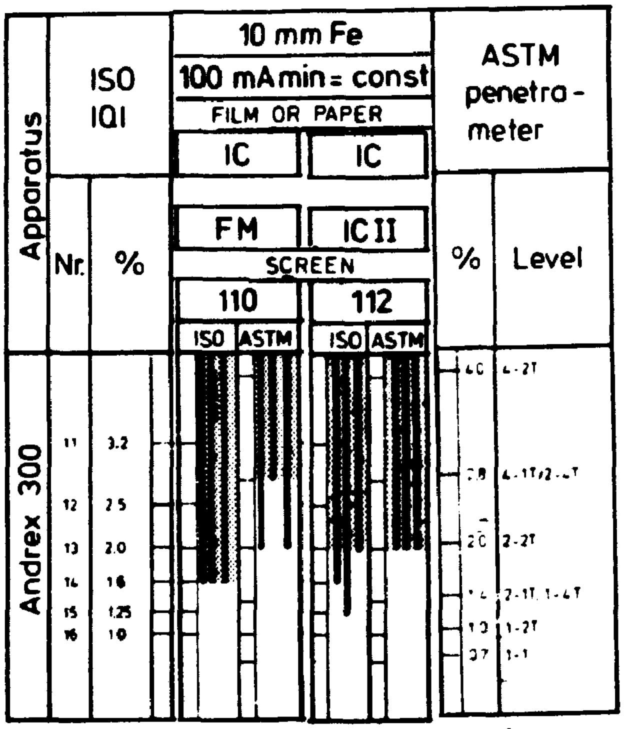

Fig. 14. Radiographic sensitivity for 10 mm Fe exposed at 100 mAmin

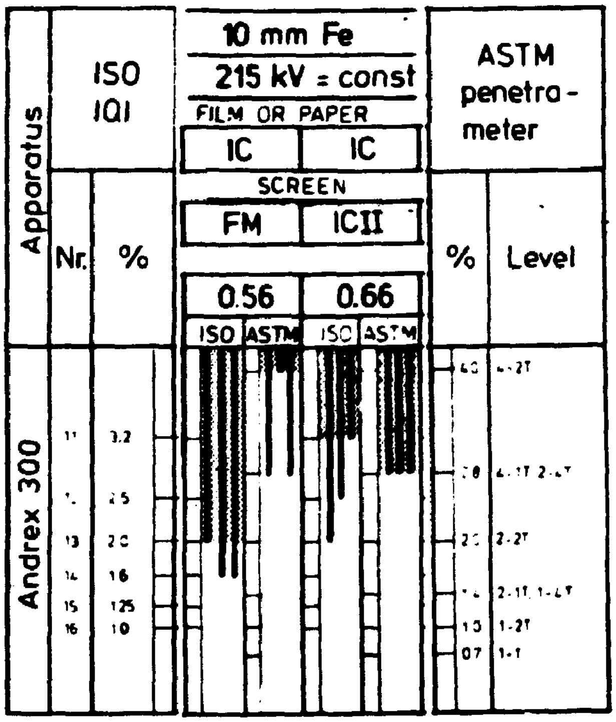

Fig. 15. Radiographic sensitivity for 10 mm Fe exposed at 215 kV

As can be seen for 30 mm Al at 25 mAmin one more IQI wire can be seen on the IC + FM combination than on the IC + ICII, whereas for the ASTM penetrameters the same sensitivity level is attained. It means that a 0.83 % IQI visibility is possible, due to the lower kilovoltage (62.5 instead of 66 kV).

Similar results were obtained for 10 mm Fe at 100 mAmin. Here also one more IQI wire can be seen on the IC + FM combination. A 1.6 % IQI visibility was reached here due to the decrease of kilovoltage (from 112 to 110 kV).

Relative speed, which can be calculated from fig. 13 and 15, is also given in table 3.

9. CONCLUSIONS

On comparing the performance of the fluorometallic screens used with radiographic paper instead of the fluorescent intensifying screens the following conclusions can be drawn:

9.1 Spectral sensitivity

Both the fluorometallic and ICII fluorescent screens show maximum sensitivity in the same wavelength range as the IC paper itself (see fig. 2).

9.2 Relative speed (see table 3)

In the low kilovoltage range for soft X-rays the relative speed of the IC + ICII combination is greater than that of IC + FM. This is due to the fact that lead present in the fluorometallic screen attenuates the soft X-rays present in the spectrum more effectively than the fluoroscent substance alone.

In the intermediate kilovoltage range (especially for Al) the IC + FM combination is about 1.5 times faster than the IC + ICII.
For higher kilovoltages and steel this advantage slowly disappears.

9.3 Contrast (see table 2)

In all investigated kilovoltage ranges, the IC + FM combination shows better contrast than that of IC + ICII. It is especially visible at lower kilovoltages for soft radiation as well as in the intermediate voltage range.

9.4 Exposure latitude (see table 2)

Because of the higher contrast the IC + FM combination shows a greater exposure latitude.

9.5 Image quality (see fig. 12 and 14)

The IC + FM combination gives a slightly better radiographic image quality (one more visible wire on the ISO IQI) when for the constant exposure technique a slightly lower kilovoltage is used than for the IC + ICII.

9.6. General conclusions

From the above analysis it is clear that the use of fluorometallic screens instead of fluorescent ones presents many advantages and can generally be recommended.

It gives higher speed and contrast and better radiographic qualities. Only in the low kilovoltage range (soft X-rays) do the advantages of higher speed disappear. In other kilovoltage ranges the use of the fluorometallic screens present an additional advantage that makes the use of separate lead filter superfluous, as lead present in the fluorometallic screens cuts off the noxious scattered radiation.

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Abstract

After the description of the fluorometallic screens and their spectral sensitivity their sensitometric properties are reviewed. Characteristic curves and exposure charts were computed for the structurix IC paper, exposed with ordinary fluorescent IC II as well as fluorometallic RCF screens. From them relative speed, contrast and exposure latitude were computed. Radiographic image quality was investigated using ISO wire IQI's and ASTM penetrometers and the constant exposure methods. The investigation has shown that it is possible and advantageous to use fluorometallic screens for paper radiography, especially above the low kilovoltage range.

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